

# OGP Abstract Template

## Title of Abstract

Influence of Sub-grid Variability on Snow Deposition and Ablation in North American Mountain Environments: Implications for Upscaling to Meso-scale Representations

## Project Duration

1 March 2003 – 28 February 2006

## Name of PI

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## Introduction

The primary runoff generation zones of the Mississippi, Colorado, Columbia, Saskatchewan and Mackenzie drainages lie in the Western Cordillera and 40-90% of this runoff is generated by snowmelt. The reduction of shortwave reflectance (from 90% to 10%) and the thawing of frozen ground during ablation of the seasonal snowcover is significant to global climate and weather patterns. Many investigators have shown that basin-scale variability in snow deposition and melt is strongly influenced by the scale of variation in topography and vegetation and that this scale is usually 10s to 100s of meters, and, from the hydrologic modeling perspective, always sub-grid or sub-catchment. This snowcover variability is highly scale dependent and not well represented in regional and continental-scale models. An improved understanding of sub-grid variability will assist in assimilating remote sensing information to model operations, and assist in parameterizing basin-scale variability in regional and global scale models.

The processes controlling the rates and magnitude of snow deposition and ablation over complex topography and in and under vegetation canopies remains one of the greatest uncertainties in the operation of land surface schemes and hydrological models over mountainous regions. For instance, very few hydrological or land surface models distinguish between snow intercepted in forest canopies, and the surface snowpack sheltered under forest canopies. No climate or water model includes the effects of exposed shrubs in collecting wind-blown snow in the alpine zone or the development of large drifts in topographically sheltered areas; these effects transform shortwave and longwave radiative exchange above the snowpack and moderate turbulent exchange between the atmosphere and underlying snowpack. Land surface schemes have at best an ad hoc representation of snow cover development and depletion that does not well represent wind redistribution of snow or actual areal albedo decay during melt and results in significant errors in surface energy balance calculations. Complex mountain terrain includes combined effects due to slope, aspect, terrain shelter, and vegetation structure that largely control both snow redistribution and drifting during the development of the snowcover, and variable patterns of snowcover energetics during melt. These effects are either poorly described or ignored in regional and global scale climate and hydrological models.

## Project Goals

The proposed project will facilitate the identification of how the predictive accuracy of mountain snowcover representations in meso-scale models can be improved. Specifically, this project will investigate how snowcover distribution and energy balance terms differ with terrain and canopy structure, and with altitude and latitude. This information will be used to identify how parameterizations of both the development and melting of the seasonal snowcover can be applied at different spatial scales in heterogeneous landscapes. The minimum complexity required to capture the essential features of snow deposition and ablation over a complex, vegetated landscape will be identified.

## Methods

The research objectives will be accomplished through complementary measurement and modeling programs. Field measurements will take place in three world-class experimental basins: Wolf Creek Research Basin (WCRB) in the Yukon Territory (Canada), the Reynolds Creek Experimental Watershed (RCEW) in Idaho, and the Fraser Experimental Forest in Colorado (Fraser). These sites form a continental-scale transect that is representative of northern cordilleran mountains, semi-arid mountainous rangelands, and high-elevation Rocky mountain regions that comprise the headwaters of western North American river systems. Specific variables that will be measured at all sites include snow depth, snow water equivalent, total solar radiation, diffuse solar radiation, thermal radiation, air and soil temperature, wind speed and direction, and relative humidity. Spatially intensive manual sampling of snow and vegetation properties will also be coordinated and completed at all three sites during a series of focused field campaigns.

Process modeling will be done at point, small catchment, and basin scales at all three experimental areas. Fine-scale model results will be used to evaluate and verify upscaled model results, and to develop strategies for spatial aggregation. At the catchment scale (0.25 to 25 km<sup>2</sup>) selected applications of detailed point models will be used to evaluate and validate grid-based model applications. Catchment scale modeling will be conducted using a similar suite of process models, but will be forced with generalized canopy, soil, and meteorological characteristics. Basin scale (25 to 2500 km<sup>2</sup>) simulations will be limited to areas over which the grid-based catchment scale models can be applied to evaluate the effectiveness of using more aggregate modeling approaches. Spatial and temporal interaction of fine-scale processes will be modeled through process algorithms developed from the point and small scale modeling efforts, and evaluated against diagnostic observations.

## Results and Accomplishments

This report covers the first year of project activity. In year 1, focused field campaigns were completed at Fraser and WCRB. Measurements completed during the field campaigns included detailed snow depth and density transects within different vegetation classes, sub-canopy solar and thermal radiation, canopy, snowpack, and soil temperatures, soil heat fluxes, and canopy thermographs. At Fraser, these measurements were supplemented with micrometeorological stations that were installed in both a homogeneous continuous and heterogeneous discontinuous conifer canopy. At WCRB, similar measurements were completed beneath a dense spruce forest, beneath tall shrubs, and over short shrub tundra on north and south-facing slopes, and on an exposed plateau. Publications using these data addressed the variability of solar transmission through uniform and discontinuous conifer canopies.

During this year additional instrumentation was installed at RCEW in preparation for the 2003-2004 winter. Microclimate and snowcover instrumentation installed at a vegetated ridge, sheltered grove and coniferous forest sites was expanded with additional stations that were installed over a big-sage canopy, within a uniform deciduous canopy, and at a low and high exposed ridge. Variables measured at these sites include radiation, temperature, humidity, wind speed, direction, snow depth, soil temperature, soil heat flux,

canopy temperature (fine-wire and IR thermocouples). Data from these stations are currently being processed and analyzed.

A symposium detailing project objectives, findings and future directions was held in September for PI and associated researchers. PI meetings were also held in July and December to coordinate research efforts.

Simulations have been initiated over the CLPX LSOS site for both the uniform and discontinuous forest canopies using models of radiation transfer through the forest canopies, turbulent flux at the snow surface below the forest, and the SNOBAL energy balance snow model. WCRB data have been analyzed and prepared for similar modeling efforts.

### Future Work

In year 2, a second intensive field campaigns will take place at WCRB and RCEW. At WCRB the 2002-2003 winter was characterized by an anomalously warm temperatures and low snowpack, whereas the 2003-2004 is proving to be relatively high snow year. Repeated measurements during this upcoming year will provide valuable data for comparison of snow processes under distinctly different climatic conditions. In addition to the measurement locations described above, additional measurement sites will be installed within a tall buckbrush canopy and an upper valley location to more completely cover areas of differing snow processes.

The first intensive field campaign will take place at RCEW in year 2. The intensive campaign will consist of detailed radiation and canopy temperature measurements and detailed snow surveys within the dominant canopy classes at RCEW from peak accumulation through melt. These data will be used to refine wind redistribution models, and understand how various canopies (i.e. conifer, deciduous, shrub) affect snow deposition and ablation.

Data analysis from year 1 investigations at Fraser and WCRB, model improvements, and development of scaling methodologies based on new data will continue during year 2.

### Publications from this project

#### Manuscripts in Review:

Hardy, JP, R. Melloh, G Koenig, D Marks, A. Winstral, JW Pomeroy, and T Link, (2004). Solar radiation transmission through conifer canopies. *Agricultural and Forest Meteorology*. (in review).

Sicart, J., J. Pomeroy, R. Essery, J. Hardy, T. Link, and D. Marks, (2004). A sensitivity study of daytime net radiation during snowmelt to forest canopy and atmospheric conditions. *Journal of Hydrometeorology*, (in review).

#### Presentations and Published Abstracts:

Hardy, J., R. Melloh, G. Koenig, J. Pomeroy, D. Marks, and T. E. Link. 2003. Solar radiation transmission through conifer canopies, International Union of Geodesy and Geophysics General Assembly, June 30 – July 11, 2003, Sapporo, Japan. *Invited Presentation*.

Hardy, J., D. Marks, R. Melloh, A. Winstral, and G. Koenig, 2003. Measured and predicted solar transmission through conifer canopies. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F390.

Link, T., M. Tribbeck, D. Marks, and A. Winstral, 2003. Inter-comparison of two models to simulate snowcover dynamics beneath forest canopies. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F391.

Johnson, J., and D. Marks, 2003. Methods to identify and correct snow water equivalent pressure sensor measurement errors to improve estimates of water stored as snow. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F389.

Marks, D., 2003. Interaction between climate, topography, vegetation, and snowcover in mountain catchments. *Proceedings of the EGS-AGU-EUG Joint Assembly*, April 6-11, 2003, Nice, France, Abstract EAE03-A-07751; CR5-1WE3O-006, p. 356. *Invited Presentation*

Marks, D. and A. Winstral, 2003. Comparison of snow cover energetics during spring at open and forested sites. *Proceedings of the EGS-AGU-EUG Joint Assembly*, April 6-11, 2003, Nice, France, Abstract EAE03-A-12927; CR5-1TU3P-1526, p. 237.

Marks, D., A. Winstral, and T. E. Link. 2003. Influence of terrain and vegetation canopies on snow cover energetics during melt, *International Union of Geodesy and Geophysics General Assembly*, June 30 – July 11, 2003, Sapporo, Japan.

Marks, D., G. Flerchinger, M. Seyfried, J. Pomeroy, R. Essery, A. Rowlands, T. Link, and J. Hardy, 2003. Influence of sub-grid variability on snow deposition and ablation in North American mountain environments: implications for upscaling to meso-scale representations, *Proceedings of the GEWEX-Americas Prediction Project (GAPP)*, July 21-24, 2003, Seattle, WA, Abstract 39, pp. 53.

Marks, D., A. Winstral, K. Elder, and J. Pomeroy, 2003. Comparing simulated and measured sensible and latent heat fluxes over snow. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F404.

Morehead, M., D. Marks, and A. Winstral, 2003. Scale dependence between hydrologic and atmospheric models. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F391.

Pomeroy, J., R. Essery, J. Hardy, A. Rowlands, and D. Marks, 2003. Uncertainty in estimating longwave fluxes to snow under forest canopies, *Proceedings of the EGS-AGU-EUG Joint Assembly*, April 6-11, 2003, Nice, France, Abstract EAE03-A-12810; CR5-1WE3O-005, pp. 356.

Pomeroy, J., D. Marks, A. Gelfan, R. Essery, J. Sicart, R. Granger, and J. Hardy, 2003. Uncertainty in measurement and modelling of longwave radiation and implications for snowmelt, *Proceedings 2003 IUGG Meeting*, June 30-July 11, 2003, Sapporo, Japan, Abstract JWH01-09P, p. C30-004.

Pomeroy, J., 2003. Snow processes: current understanding and future prospects. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F389.

Pomeroy, J., 2003. The interaction of snow physical processes with vegetation in open and forested biomes. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F399.

Quinton, W., and J. Pomeroy, 2003. Flowpath transformations of precipitation chemistry in an arctic tundra catchment. *Eos, Transactions, American Geophysical Union*, vol. 84, no. 46, p. F401.

Winstral, A., and D. Marks, 2003. Simulating wind fields and snow redistribution using terrain-based parameters to model snow distribution, energy fluxes, and melt over a semi-arid mountain catchment. Proceedings of the EGS-AGU-EUG Joint Assembly, April 6-11, 2003, Nice, France, Abstract EAE03-A-07602; CR5-1WE3O-007, p. 356.

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